APPENDIX A-2 - NON-TREATMENT OPTIONS

1.01 INTRODUCTION

Non-treatment options rely on a water management approach to address undesirable substances in water supplies to eliminate or minimize the need for treatment. Non-treatment options should therefore be considered in the early planning stages for mitigation of any chemical quality problem in a water supply system. Effective water management techniques can avoid the high costs associated with design and construction of a treatment facility, construction of additional pipelines, operation and maintenance (O&M) of a treatment system, treatment system waste disposal, land purchase, etc.

Non-treatment options commonly use the existing water system infrastructure and are less disruptive and less complex to operate than treatment options. Due to lower costs and lack of the stigma surrounding consumption of treated water, non-treatment options generally receive more positive public response than treatment options.

Assessment of the feasibility of a non-treatment solution should be viewed as an essential first step toward achieving water quality compliance. The mitigation action should be an integrated solution that accounts for the following:

- Effective use of water system assets
- Operation characteristics and needs of the water system
- Source and distribution of the targeted chemical constituent (in this case arsenic)
- Impacts of other water quality parameters (nitrate, total dissolved solids, etc.)
- Impacts on other water users and the environment
- Cost effectiveness of the mitigation option (treatment vs non-treatment)
- Consumer acceptance
- Regulatory compliance

For water systems that rely chiefly on groundwater, low cost hydrogeologic investigation methods are available to assess the feasibility of modifying the use or design of a well field to achieve arsenic compliance, either without treatment or with a substantially reduced level of treatment. These investigations can provide a critical understanding of the specific source of the arsenic problem and the distribution in the well field so that appropriate actions can be planned. Even if the investigation results indicate that the need for treatment can not be eliminated, the data obtained is valuable for long-term operation of the well field and for optimum design of a treatment alternative. Well rehabilitation may be conducted as part of the hydrogeologic investigation program as it is beneficial, whether or not treatment is used.

Significant cost savings and benefits can be achieved by implementing a non-treatment option for arsenic mitigation. Hydrogeologic investigations are conducted in a logical, phased approach to: 1) maximize cost efficiency; 2) allow the scope of work to be modified as necessary based on interim results; and 3) provide appropriate milestones at which to determine feasibility of a non-treatment solution or integration with a treatment solution.

2.0 ARSENIC OCCURRENCE IN GROUNDWATER

The feasibility of using non-treatment options, such as well or well field modification, to meet the arsenic standard improves where arsenic concentrations vary vertically and/or horizontally in an aquifer or sequence of aquifers. Vertical variations in arsenic concentrations occur most commonly in multi-layered aquifer systems. Sedimentary and igneous fractured-rock aquifers also provide opportunities where confining units or other features separate groundwater flow in fracture systems. Horizontal variations in arsenic concentrations can occur in nearly any aquifer system.

For example, data obtained from the Indian Bend Wash area, Scottsdale, Arizona, indicated that arsenic concentrations increased from the upper to lower layers of the aquifer. Concentrations ranged from less than 2 to 8.4 parts per billions (ppb) in the Upper Alluvium unit and from less than 2 to 49 ppb in the Lower Alluvium unit. This non-uniform distribution can be used in the design of new wells or modification of existing wells to selectively obtain groundwater from the low-arsenic aquifer zones.

2.1 Natural Occurrence of Arsenic in Groundwater

The natural occurrence of arsenic in groundwater can generally be characterized as follows:

- arsenic is derived from parent materials in soil and rock, typically iron-oxide minerals.
- arsenic concentrations in soil and rock are typically higher in groundwater.
- arsenic occurs in hydrothermal sulfide minerals associated with metallic ore deposits.
- volcanic rocks are more commonly associated with high arsenic concentrations in groundwater than are granitic rocks.
- arsenic is most abundant in the clay minerals of sediments, particularly those that contain iron, manganese, and aluminum oxides.
- arsenic is commonly more abundant in deeper aquifer zones than in shallow aquifer zones.
- arsenic concentrations in groundwater are elevated near centers of evaporation, such as playa limestone and gypsum deposits.
- arsenic commonly occurs in groundwater associated with geothermal springs.

Common source minerals for arsenic include arsenopyrite, iron pyrite, and chalcopyrite. Arsenic is found in groundwater in an oxidized state as arsenate [As(V)] and in a reduced state as arsenite [As(III)]. Arsenite is approximately 60 times more toxic than arsenate.

2.2 Mobility of Arsenic in Groundwater

The movement of arsenic occurs chiefly by two processes: adsorption/desorption; and precipitation/dissolution. Adsorption/desorption is the process of electrostatic bonding or release of arsenic from soil and rock particles, and is affected by changes in pH, oxygen level, and the presence of competing ions. Arsenic ions adsorb to iron and aluminum oxides, and clay minerals where conditions are chemically neutral (pH near 7). Arsenate is more strongly adsorbed than arsenite, and is therefore, less mobile. Alkaline groundwater (pH of 8 or more) provides more favorable conditions for desorption and mobility of arsenic. Oxides of phosphorus, molybdenum, selenium, and vanadium compete with arsenate for adsorption sites in aquifer media, and therefore may increase the mobility of arsenate in groundwater.

Precipitation/dissolution is the process of moving arsenic out of or into solution with groundwater. Arsenic co-precipitates out of groundwater with iron, barium, cobalt, nickel, lead, and zinc. Arsenic tends to dissolve into groundwater from iron, copper, zinc, arsenic, and lead sulfides. Dissolving of solid minerals will mobilize arsenic in both solid and adsorbed phases. Iron oxide is a source of arsenic in groundwater as it dissolves, but tends to remove arsenic from groundwater when it is precipitated.

2.3 Human-related Sources of Arsenic in Groundwater

Human-related sources are commonly agricultural, industrial, and municipal. Agricultural sources include: pesticides; cotton-gin wastes; poultry and swine wastes (from arsenic food additives); and phosphate fertilizers. Industrial/municipal sources include: wood preservatives; wet-cell batteries; semiconductors; cancer drugs; phosphate detergents in wastewater; industrial solvents; petroleum contamination; and landfill leachate.

3.0 CHARACTERIZATION AND MITIGATION OF ARSENIC IN WATER SYSTEMS

In the effort to mitigate arsenic or other chemical constituents, it is important first to understand the source and distribution of the substance in a water supply system and to use a phased approach to achieve mitigation. The phased approach: 1) maximizes cost efficiency; 2) allows the scope of work to be modified as necessary based on interim results; and 3) provides appropriate milestones at which to determine feasibility of a non-treatment solution or integrated treatment/non-treatment solution. A three-phased approach can be used to characterize the occurrence of arsenic in a water system and can provide the basis for achieving compliance with the arsenic standard by applying non-treatment options exclusively or integrated with treatment options.

3.1 Phase 1 - Investigation and Feasibility Assessment

Phase 1 includes, but is not limited to, one or more of the following tasks, depending on the water system:

- review of existing data and/or acquisition of new data to evaluate subsurface conditions, determine arsenic distribution in a defined study area, and identify impacted wells;
- downhole video surveys of affected wells to verify well construction details and condition;
- downhole fluid-movement tests and depth-specific sampling under pumping and non-pumping conditions at the affected wells to determine the relative contribution of flow and arsenic from different aquifer zones and, if appropriate, at varying pumping rates;
- pumping tests to estimate aquifer hydraulic properties, well efficiency, and sustainable well yield;
- borehole geophysical logging to verify occurrence and condition of annular seals and to characterize aquifer lithology; and
- analysis of aerial and satellite photos, field mapping, and, where appropriate, conduct surface geophysical surveys to identify fracture systems or other pertinent geological features that may be related to the occurrence or distribution of arsenic.

Based on results of these investigations, it may be determined that conditions are favorable for a non-treatment option and an appropriate mitigation measure could then be designed. If conditions are not favorable for a non-treatment option, or if a non-treatment option is not anticipated to completely mitigate elevated arsenic concentrations, then a treatment alternative could be designed and implemented. Whether or not a non-treatment option is implemented, the data obtained during Phase 1 are valuable for managing a groundwater system and can be used to optimize a treatment option, thereby reducing costs.

3.2 Phase 2 - Implementation of Well Mitigation Measures

Based on results of Phase 1, a strategic water management plan can be prepared to meet present and future water demand through integration of one or more of the following measures with the existing water supply system:

- modify pumping rates and/or pumping schedules to discontinue or limit the use of high-arsenic wells and to maximize pumping from low-arsenic wells;
- blend the water supplies from different wells, surface water, or other sources;
- rehabilitate existing wells to improve yield from low-arsenic aquifer zones;

- modify existing wells to seal off high-arsenic aquifer zones or to increase the yield from untapped low-arsenic zones;
- install properly designed replacement wells, located on the basis of system need and favorable hydrogeologic conditions; and
- identify alternate water supplies, and modify or add infrastructure to use them.

Modification of the screened interval in a well and optimization of the pumping rate can be considered a form of blending of water yielded from different aquifer zones. Because this blending occurs within the well, it can provide a more consistent chemical quality and requires less control to maintain than above-ground blending systems.

3.3 Phase 3 - Monitoring the System

Implementation of a non-treatment option should be accompanied by development of an ongoing monitoring plan to ensure arsenic compliance. Although the need to monitor system features and groundwater conditions during implementation of a non-treatment arsenic compliance approach results in some initial capital and ongoing operation costs, these costs will be small in comparison to costs associated with O&M, waste disposal, and system monitoring required for a treatment approach.

Blending water from multiple wells and other sources requires a high degree of control to maintain proper pumping rates of different wells in the system. For blending purposes, it is essential to ensure that high-arsenic wells are shut down automatically if pumping from associated low-arsenic wells is decreased or stopped. Monitoring commonly consists of periodic water sampling for selected chemical analyses and use of a Supervisory Control and Data Acquisition (SCADA) system. Use of an appropriate SCADA system can provide the level of control necessary to maintain reliable and continuous compliance. SCADA systems can be designed to monitor and record water levels and pumping rates, control pumping rates, prevent the operation of high-arsenic wells unless low-arsenic wells or other water sources are in use, deliver data to offices telemetrically, and provide alarms to notify operators of problems and the need for action.

Ongoing monitoring of chemical quality in a groundwater system is necessary for projecting continued effectiveness of the non-treatment solution. Installation of depth-specific sampling access in production wells provides a method to verify that the mitigation approach selected for the well field is optimal with respect to the arsenic distribution in groundwater. Alternatively, monitor wells can be specifically designed and installed to provide data critical to ongoing operations.

4.0 SUMMARY

In the process of finding the best approach to mitigate poor chemical quality in a groundwater supply system, cost effective hydrogeologic investigations should be conducted first to characterize the aquifer conditions, define the source and distribution of the targeted constituent, evaluate the construction details and operational features of the existing well field, and determine if compliance can be achieved using a non-treatment approach. Implementation of a non-treatment alternative should be accompanied by an appropriate monitoring program to ensure reliable and continuous compliance with drinking water standards.

The benefits of an effective non-treatment approach include:

- lower costs due to avoidance of the need for design and construction of a treatment facility, construction of additional pipelines, O&M of a treatment system, treatment system waste disposal, land purchase, etc.;
- use and integration of the existing water system infrastructure;
- less disruptive and less complex to operate than treatment options:
- lower cost for monitoring compliance;
- better public acceptance than for treatment options; and
- decrease in the level of treatment required and in the cost of a treatment option, if the necessity for treatment can not be eliminated.

The selected mitigation action should be an integrated solution that accounts for effective use of water system assets and operation characteristics/needs, source and distribution of the targeted chemical constituent, effects of other elements of water quality, impacts on other water users and the environment, cost effectiveness, and acceptability by consumers and regulatory agencies. Regardless of the mitigation approach finally selected, results of the hydrogeologic investigations are valuable for long-term operation of the well field and for optimum design of a treatment alternative.